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STUDIES ON THE PHYSIOLOGY OF REPRODUCTION IN THE DOMESTIC FOWL.

III. A CASE OF INCOMPLETE HERMAPHRODITISM.¹

RAYMOND PEARL AND MAYNIE R. CURTIS

ORIGIN AND GENERAL CHARACTER OF SPECIMEN.

From a chick hatched in the spring of 1907, at the Maine Agricultural Experiment Station, there developed the bird which forms the subject of this paper. This bird was a Barred Plymouth Rock and when adult presented externally the general appearance of a normal hen of this variety, so far as the characters body form and plumage color were concerned (cf. Plate I.). As the photograph in Plate I. shows, however, the head and neck resembled these parts in a cockerel. This resemblance was especially remarkable in respect to the size and shape of the comb and wattles. The comb was obviously much larger than the comb of a normal Barred Plymouth Rock hen and looked exactly like the comb of a male bird. This was also true of the wattles.

The dimensions² of the comb of this bird were as follows :

Length.....	88.4 mm.
Calculated height.....	25.1 mm.
Area.....	22.2 cm. ²

For normal adult Barred Plymouth Rock females the following average values for comb size have been found :³

Mean length.....	50.80 ± .56 mm.
“ calculated height.....	10.57 ± .23 “
“ area.....	5.59 ± .17 cm. ²

It is evident from these figures that the comb in this specimen greatly exceeds in size the average for females of the variety.

¹ Papers from the Biological Laboratory of the Maine Agricultural Experiment Station, No. 13.

² Made in accordance with the methods described by R. and M. D. Pearl in a paper “Data on Variation in the Comb of the Domestic Fowl,” *Biometrika*, Vol. VI., pp. 421-423.

³ Pearl, R. and M. D., *loc. cit.*, p. 427.

In regard to behavior this bird resembled a normal hen rather more than a cock. She was never heard to cluck, however, or to make any of the sounds which normal active hens make in the course of the day's work. This bird probably never laid an egg, though we are unfortunately not able to make an absolute statement on this point. The egg records of the station show an egg to the credit of this bird on November 7, 1907. This was the only egg ever recorded for this bird, and it is undoubtedly an erroneous record. As will presently appear, the condition of the sexual organs was not such as to indicate that they had ever been functional.

Cockerels placed in the pen with this bird would try to fight with her as if she were a cockerel; but she would not fight.



FIG. 1. Outline of the lateral aspect of the comb of the Barred Plymouth Rock hen described in this paper. This outline is actual size.

We have no evidence that a cockerel ever attempted copulation with this bird. These facts are of interest in relation to the question of the basis of sex-recognition and the assortative mating known to occur among fowls. Is a normal pullet with an unusually large comb less likely to have her eggs fertilized than a bird with a smaller comb?

This bird was observed occasionally to take the position of a cockerel about to crow and attempted to crow but never succeeded in very closely approximating the sound of a normal cock bird. The bird was never seen to attempt to tread a hen.

AUTOPSY.

The appearance and behavior of this bird led to the suspicion that it represented a case of true hermaphroditism. On August 24, 1908, the bird was killed and a post mortem examination made. The weight of the body after bleeding was 2,725 grams. The body cavity contained much fat. The alimentary tract and attached viscera were entirely normal. The following measurements were made :

From gizzard to origin of cœca.....	167 cm.
Longest cœcum.....	22 "
From origin of cœca to cloaca.....	13 "

The following weights were taken :

Gizzard.....	125 gms.
Liver.....	44 "
Heart.....	9.5 "
Spleen.....	4.5 "

On the left side of the body was a normal oviduct. There was an ovary in the usual position. It was of about the size of the ovary of a laying hen after the removal of large yolks. It had a coarsely granular appearance and showed many folds. There were no eggs visible and its surface did not have the ragged appearance, due to ruptured follicles, which is characteristic of the ovaries of laying hens. The rest of the urinogenital system was completely covered by fat. The part of the body containing this organ system was hardened in formalin for further dissection.

GROSS ANATOMY OF REPRODUCTIVE ORGANS.

Dissection confirmed the suspicion of hermaphroditism. On the left side were the female-like reproductive organs described above while on the right side there was a set of organs similar to those of the normal male. The gross anatomy of the reproductive system in this bird is shown in Plate II., Fig. 1.

The female organs were more nearly normal than the male. The ovary, like a normal ovary, was ventral to the cranial lobe of the left kidney, covering, when viewed from the ventral side, all but the caudo-lateral angle of this lobe. It extended past the cranial margin of the kidney in the hermaphrodite nearly to, and in the normal hen with which comparisons were made, slightly beyond the fourth rib. In the hermaphrodite the ovary

was developed less on the medial side than in the normal hen. The measurements of greatest length and breadth of ovary in the hermaphrodite were 29 mm. by 16 mm. while in the normal hen they were, excluding the projecting yolks, 34 mm. by 20 mm. The ovary was attached to the body wall near the middle line by a thick stalk-like portion. This appeared perfectly normal. Its longest dimension (cranio-caudal) was 15 mm. compared to 18 mm. in the normal bird. The external appearance of the ovary was quite different from that of a normal ovary. It seemed to be a coarsely granular but otherwise homogeneous mass covered by peritoneum and minutely and very irregularly folded. It did not have the ragged appearance of the normal ovary and the minute folded masses did not look like the yolks of similar size in the normal ovary. They seemed to be folds on the surface of a homogeneous mass rather than small spheres of yolk enclosed in follicles.

The oviduct was normal in appearance and in position. The mouth of the funnel faced the ovary while the cranial ends of the lips were fused and extended across the left kidney to the fourth thoracic rib some distance laterad of the cranial end of the ovary. The caudal ends of the lips also fused and were attached to the ventio-median margin of the ligament which holds the convolutions of the oviduct in place. The oviduct presented the same principal convolutions as a normal active oviduct. It was larger than the oviduct of the adult hens we have examined which had never laid and the ovaries of which did not show a number of yolks. Table I. gives the lengths of the oviducts we have been able to examine in this condition.

TABLE I.

Dimensions of Oviducts of Pullets which have Never Laid and which have no Growing Yolks on Ovary. Hermaphrodite Included for Comparison.

Band Number of Bird.	Length of Oviduct in cm.	No. of Yolks Above 1 cm. on Ovary.	Total Number of Eggs Laid.
Hermaphrodite			
16 D	47.0	0	0
129 E	13.0	0	0
297 E	20.0	0	0
222 E	23.5	0	0

The length of the oviduct of the hermaphrodite hen 16 as

given in the first line of this table is 47.0 cm. This is just twice the length of the next shorter oviduct, that of hen 222 E. The oviduct is however smaller than in hens actively engaged in egg production in the middle of a laying period. It compares most nearly in size with the oviduct in hens which have ceased laying from 5 to 16 days before examination, or to those with 4 to 6 large yolks on the ovary. In order that this comparison may be readily made Table II. is introduced. This table is compiled from records in the archives of the laboratory and gives certain data in regard to normal hens having oviducts between 44.5 cm. and 50.5 cm. long, *i. e.*, of approximately the same length as that of the hermaphrodite hen No. 16. The table includes the following data: (a) length of oviduct in cm.; (b) the number of yolks 1 cm. or more in diameter on the ovary at the time of autopsy; (c) the number of days elapsed since the last egg was laid. In case the bird never laid the sign ∞ is used to denote this fact.

TABLE II.

Data from Normal Hens on Oviducts of Same Size as that of Hermaphrodite Bird.

Band Number of Bird.	Laboratory Autopsy Number.	Length of Oviduct in cm.	Number of Eggs 1 cm. or More in Diameter on Ovary.	Number of Days Since Last Egg Was Laid
Hermaphrodite				
16	175	47.0	0	∞ (?)
260 D	117	47.0	0	8
15 D	124	50.0	0	5
213 D	133	46.0	0	7
788 D	137	45.0	0	9
38 D	151	46.0	0	8
405 D	171	50.0	4	9
317 E	179	50.0	4	∞
480 E	202	49.0	2 absorbing	16
314 E	236	48.5	2 "	10
96 E	237	49.0	6 "	∞
429 E	248	48.5	14 (hard, absorbing)	9

From the table it is apparent that the oviduct in the hermaphrodite hen was in essentially the same condition as that of a normal hen which has recently completed an egg-laying period (clutch).

Internally the oviduct of the hermaphrodite was differentiated into the regions characteristic of the normal oviduct. The funnel walls were thin and transparent. Grandular ridges appeared

at the end of the funnel and became gradually heavier and higher. In the albumen-secreting portion of the tube they were heavy, high and irregularly lobed. The ridges at the cranial end of the isthmus were thin and straight but did not preserve that character so strictly as in a normal oviduct, so that near the shell gland they resembled the ridges in the albumen-secreting portion. The shell gland ridges were high, very irregular and much lobed. These turned dark in the preserving fluid as we have often noticed to be the case with normal oviducts. The vagina had the characteristic low straight ridges. The dimensions of the various parts of the oviduct were as follows :

Length of funnel neck.....	2.5 cm.
Width of flattened tube at point where funnel passes into albumen portion.....	0.6 "
Length of albumen portion.....	18.5 "
Width of flattened tube at widest part of albumen portion	0.9 "
Length of isthmus.....	7.0 "
Length of shell gland.....	7.5 "
Width of widest part of shell gland.....	2.0 "
Length of vagina	11.5 "

The opening of the oviduct was in the normal position, slightly to the left of the midventral line. The margin of the opening was folded, but was inconspicuous while in a laying hen it protrudes a little into the cloaca. A large probe was passed from the vagina into the cloaca demonstrating a natural opening between these organs.

The left suprarenal body was covered by the cranial end of the ovary as in normal cases.

Directly opposite the middle of the ovary on the left side of the body was a small irregular, though generally ovoid organ, the testis (Plate II., *T*). This organ was 9 mm. in length by 6 mm. in greatest breadth. It was attached to the body wall by its broad side with the more convex side median and the nearly straight side lateral. This organ did not appear macroscopically like a testis but looked to the naked eye or through the hand lens, like a small mass of the same sort of tissue as the ovary already described, but covered with an additional layer of connective tissue which obscured the minute foldings.

From the lateral side of the testis a duct passed to the cloaca

running parallel to the median line and ventral and lateral to the ureter. This tube was nearly straight throughout its course, but had a few convolutions near the cloacal end. It had the position and appearance of a normal vas deferens in a young cockerel. The tube was heavy walled and gradually increased in diameter caudad. Sections showed that this duct had a definite lumen. There was no enlargement comparable to a seminal vesicle. It was not possible to demonstrate an opening into the cloaca.

HISTOLOGY OF THE LEFT GENITAL GLAND (OVARY).

The left genital gland was much less finely lobulated than a normal ovary. The large lobules had smooth contours. The organ was covered with a layer of peritoneum. Over most of the surface the cells of this layer were nearly cubical but in some portions they were shorter than broad while in other regions they were nearly twice as tall as broad. Over a few small areas there was an outward proliferation of this epithelium so that evaginated folds of the epithelium four to six cells deep projected from the surface. In a few cases these evaginated ridges were still further folded along their lateral margins.

Beneath the peritoneal layer was the tissue which formed the bulk of the organ. This was a highly cellular but much vacuolated tissue, the cells of which were not unlike the cells of the stroma of a young ovary. This tissue was nearly uniform throughout the organ. In the vacuoles of this tissue were found, in many portions of the organ, irregular non-cellular masses which stained deeply with acid stains, especially eosin. Some of these masses were surrounded by a single layer of very much flattened cells. They did not appear like ova nor did the surrounding cells resemble normal follicle cells. In the part of the organ ventral to the suprarenal body were a few spherical portions of the stroma-like tissue which were more dense and took a deeper stain with hæmatoxylin. These portions did not differ in other particulars from the surrounding tissue.

The stroma-like tissue contained few blood vessels but a highly vascular connective tissue penetrated the organ from the stalk. This tissue appeared like a core to the organ projecting into the larger lobules in tongue-shaped masses.

No Graaffian follicles or Pflüger's tubes were found, though series of sections from all parts of the gonad were examined. The general histological structure of the organ was such as to indicate that it was in a degenerating condition at the time the bird was killed. This process of degeneration had gone so far that nothing like normal ovarian tissue was to be found. Whether at any time in the life of the bird any part or all of the ovary had been normal in structure, it is impossible now to say. The condition of the gland at death afforded no certain evidence either for or against this view. That oögenesis, however, could not have gone beyond early stages during the later life of the bird is made probable by the fact that it did not lay (except for the single doubtful egg noted on p. 272), although possessed of a normal oviduct.

The net result of the microscopical examination of the left genital gland, which had the normal anatomical relations of an ovary, is negative.

HISTOLOGY OF THE RIGHT GENITAL GLAND (TESTIS).

The limiting membrane of the right genital gland was not very thick and was poorly preserved in our sections. Such parts of it as were intact seemed to have a cellular outer layer with a fibrous inner layer. We could not be sure of further histological details nor could we determine the extent of this tunic.

The gland contained no normal seminiferous tubules but showed evidence of tubular origin. The central portion was more dense than the periphery and in this more dense portion a few places showed the cells arranged as if small cellular rods had been cut in various planes. These rods might be considered tubes without lumen. They were formed by a single layer of nearly cubical cells, about the size and form of the epithelial cells of the seminiferous tubules at the age when these form a single layer nearly filling the lumen. Around these rods was a thin layer of fibrous tissue. Between the dense central portion and the periphery the epithelial cells gradually disappeared so that the greater portion of the gland appeared to be a connective tissue skeleton representing the basal membranes of the tubes, and the intertubular stroma of the young gland. Most of the tubes formed by the remaining basal membranes contained a few

cells but these were irregular and had lost their epithelial character. In some of the tubes were eosin-staining non-cellular masses like those found in the left genital gland. In the right gland we did not find cells surrounding these masses.

On the dorsal side of the organ was a mass of tubules. Those seen in each section varied considerably in diameter but they were much smaller toward the cranial end of the organ. This mass of tubules extended the full length of the testis. The tubes were lined with simple, heavily ciliated, columnar epithelium. Outside this, especially in the larger tubules, could be distinguished one or more layers of smooth circular muscle cells. The tubes were imbedded in connective tissue. This tubular structure was in all essential particulars precisely like a normal epididymis and without any question represents that organ. A photograph of a section through the epididymis is shown in Plate II., Fig. 2. The magnification used in this figure is low, but on the original negative the cilia on the cells lining the tubes can be plainly seen.

On the median side of the testis and lying for the most part at the side of the epididymis, though in some portions extending between the gland and the epididymis, was a mass of very vascular connective tissue.

Sections of the vas deferens at about the middle of its length showed it to be a tube considerably larger in diameter than the largest part of the epididymis. It was lined with columnar epithelium showing, in some sections, two rows of nuclei close together. In some sections cilia could be distinguished, but they were not so easily demonstrated as in the epididymis. There was a subepithelial layer of non-muscular tissue, probably the mucosa, and outside this a thick layer containing smooth muscle fibers. We were unable to distinguish different muscular layers in our sections.

The lumen of the vas deferens and also parts of the epididymis contained masses which stained strongly with eosin. These masses included irregular fragments that took the chromatin stain.

In general, the histological study of the right genital gland led to the same conclusion as did that of the left, namely, that we were dealing with a degenerating structure. As is indicated in the

foregoing description, however, the right gland approached somewhat more nearly to the normal than did the left. Whether this organ was even functional, however, in the sense of containing actively dividing spermatogonial cells, cannot be determined from the evidence afforded by the histology of the gland at death. It may or may not have been. One cannot tell. So then again our results on the question as to whether actual spermatogenesis occurred in this hermaphrodite fowl are negative. All that can be positively affirmed is that at the time when the bird was killed, both sexual glands were in an inactive and degenerating condition.

DISCUSSION OF RESULTS.

The case above described presents a number of points of considerable theoretical interest which we may now, with the facts in hand, proceed briefly to discuss.

The first point to which we would direct attention is the peculiar combination or correlation of sexual characteristics (primary and secondary) which existed in this bird. Externally it presented a condition essentially similar to the rarely observed antero-posterior gynandromorphism of insects. Anteriorly the bird was male in its external somatic characters; posteriorly it was female. The truth of this statement may be demonstrated in a striking manner by placing the edge of an opaque card along a line connecting the letters *a* and *b* in Fig. 1 of Plate I. and turning the card about this edge as an axis so as to expose alternately the anterior and posterior parts of the bird. When the card covers the posterior part of the bird what one can see (*i. e.*, the anterior part) is unmistakably and indubitably male. On the contrary, when the anterior part is covered by the card, what of the bird is then to be seen is equally unmistakably female. The "maleness" and "femaleness" of these two portions of the body extend to the most minute details of structure, perhaps not apparent to anyone not perfectly familiar through first-hand practical experience with poultry and particularly Barred Plymouth Rocks. Thus the beak—which is not ordinarily reckoned as a secondary sexual character—in this bird is to the fancier unmistakably that of a male.

It is certainly a remarkable fact that with this perfectly clear

and definite somatic gynandromorphism there is associated an absolutely inactive condition of the primary sexual organs, so far as the functions of spermatogenesis and oögenesis are concerned. The case shows clearly enough that the secondary sexual characters of both sexes *may* exist without the accompaniment of functioning germinal epithelium in the same individual. It does *not* prove that the secondary characters may originally *develop* in the absence of the functioning of the primary glands, because of the uncertainty as to whether either of the glands was ever functional in this specimen.

There has accumulated in recent years a considerable mass of evidence,¹ particularly from medical, surgical and gynecological workers, tending to show that the development of secondary sexual characters is in some way controlled through internal secretions (containing hormones) produced in some part or parts of the primary sexual apparatus. While the general fact of such a relationship is now to be regarded as quite definitely established, the details of the process are as yet by no means worked out. Whether these secretions are elaborated in cells of the germinal epithelium proper, from interstitial or stromal cells, or from the accessory parts of the reproductive apparatus (*e. g.*, epididymis, oviduct, etc.) is, in general, still unknown. It might at first thought be supposed that the present case, inasmuch as the glands are degenerate and non-functional whereas the accessory male and female organs (epididymis, vas and oviduct) are complete and normal, afforded evidence in favor of the view that these latter organs are sources of internal secretions influencing secondary sexual characters. Any presumptive warrant for such an inference, however, is largely if not entirely taken away by evidence of another kind. We have conclusively shown, for example, in unpublished experimental work that complete or partial removal or ligation or section of the oviduct in the domestic fowl, undertaken before or after the oviduct has become functional, is without any effect whatever on the development or

¹ It seems unnecessary to print *in extenso* here the long list of literature which exists on this subject. An introduction to this literature will be found in Morgan's "Experimental Zoölogy," Chapters 28 and 29, and in Bayliss, W. M., and Starling, E. H., "Die chemische Koordination der Funktionen des Körpers," *Ergeb. der Physiol.*, Jahrg. V., pp. 664-697, 1906.

persistence of the female secondary sexual characters. The fact that in man vasectomy (practised, for example, in Indiana for the sterilization of criminals and certain other undesirable citizens) produces no effect whatever on secondary sexual characters or the sexual appetite is again evidence in the same direction.

The present case, of course, affords no direct evidence as to whether a secretion influencing secondary sexual characters may not be produced by the interstitial or stromal cells.

A further point of considerable interest lies in the fact that in this bird we have a fully developed, normal, and so far as can be told, entirely functional oviduct in the absence of a functional ovary. Normally in the hen the oviduct is in an atrophied, non-functional condition at times when laying is not going on, *i. e.*, when the ovary is not functioning. In the young pullet the oviduct stays in an infantile condition until the oöcytes begin to enlarge by the deposition of yolk just before laying begins. As the yolks approach the size at which they are separated from the ovary the albumen-secreting and other glands of the oviduct become enormously enlarged and the whole organ passes into the "laying condition." After laying stops the glands quickly atrophy and the whole organ goes back to the adolescent condition. In other words, there is in the normal bird a close correlation between the functioning of ovary and oviduct. There is, of course, a similar apparent correlation between ovary and uterus in mammals.¹ Now in this hermaphrodite specimen the correlation is apparently upset. We have the oviduct in "laying condition" in a bird in which the ovary is absolutely non-functional so far as ovulation is concerned. The two cases of hermaphroditism in the domestic fowl described by Shattock and Seligmann² essentially parallel ours in this regard. In both cases they found a well-developed

¹ Here the brilliant work of Dr. Leo Loeb is establishing, by means of analytical experimentation, the causal factors in the physiology of the uterus. Cf. Loeb, L., "The Production of Deciduomata and the Relation between the Ovaries and the Formation of the Decidua," *Jour. Amer. Med. Assoc.*, Vol. L., pp. 1897-1901. June 6, 1908.

² Shattock, S. G., and Seligmann, C. G., "An Example of True Hermaphroditism in the Domestic Fowl, with Remarks on the Phenomenon of Allopteratism," *Trans. Pathol. Soc. London*, Vol. 57, pp. 69-109, Plate I., 1906. "An Example of Incomplete Glandular Hermaphroditism in the Domestic Fowl," *Proc. Roy. Soc. Medicine*, Vol. I., pp. 3-7, 1907.

oviduct, though the ovary was distinctly not in *ovulating* condition.¹ These cases point strongly to the idea that the mutual interrelationship between ovary and oviduct in birds is very far from being of such a simple character as one would be led to infer from observation of normal specimens. Here, as in other instances, teratology may furnish the clue for the elucidation of a normal physiological process.

SUMMARY.

The purpose of this paper is to describe in detail a case of incomplete hermaphroditism in the domestic fowl. It is shown that:

1. In its external somatic characters the specimen was an antero-posterior gynandromorph.
2. Internally the bird possessed on the left side a large, lobulated gland in the position and anatomical relations normal to the ovary. There was also a fully developed, normal oviduct, in functional condition on the left side of the body.
3. On the right side of the body was a small organ in the position and anatomical relations normal to the right testis. Attached to this organ was a normal epididymis and vas deferens leading to the cloaca.
4. Microscopical examination showed that both sex glands were in a condition of extreme degeneration. Neither spermatogenesis or oögenesis could be found in any part of either gland.
5. Certain theoretical aspects of the case are discussed.

¹ These authors did, in these cases, succeed in finding some evidence of actual oögenesis, but not of ovulation, either past or prospective.

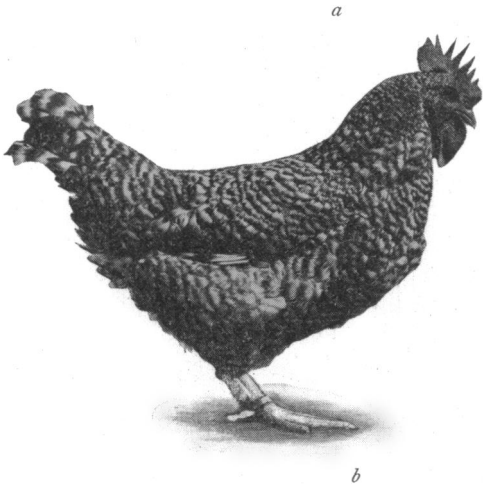
EXPLANATION OF PLATE I.

Showing the hermaphrodite specimen described in the text. A normal male and female of the Barred Plymouth Rock breed are shown for comparison.

FIG. 1. Hermaphrodite specimen. A line connecting the letters *a* and *b* marks the division region between the male and female portions of the gynandromorphic condition. Cf. text, p. 280.

FIG. 2. Normal Barred Plymouth Rock cockerel.

FIG. 3. Normal Barred Plymouth Rock pullet.



b

FIG 1



FIG. 2.

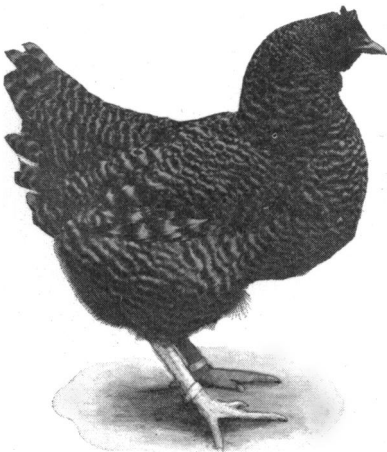


FIG. 3.

EXPLANATION OF PLATE II.

FIG. 1. Photograph showing the gross anatomy of the genital organ of the hermaphrodite specimen. *O*, ovary. *F*, funnel mouth of oviduct (*ostium tubæ abdominale*). *S*, region of shell gland of oviduct. *T*, testis. *V.D.*, vas deferens. *U*, right ureter. A black card is placed behind the vas deferens and ureter in the lower portion.

FIG. 2. Microphotograph of section through epididymis. Obj.: Spencer 32 mm.; 6× compensating ocular.

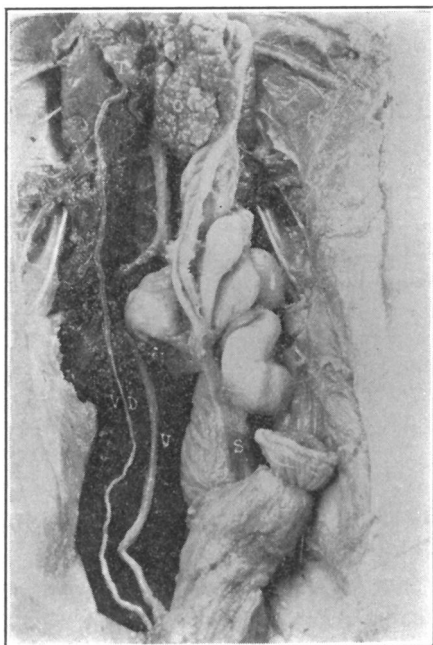


FIG. 1.

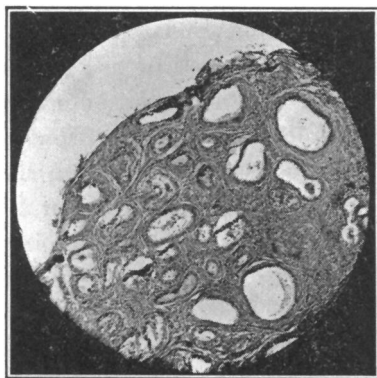


FIG. 2.